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APPROACHES AND TOOLS FOR SUSTAINABLE MANAGEMENT OF FISH RESOURCES IN THE MEKONG RIVER BASIN

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Abstract

This paper details the approaches and tools developed at ICLARM to contribute to the sustainable management of fish as a food resource in the Mekong River Basin.

Multiple partnerships have been established in order to gather, compile, analyse and compare existing data on fish resources. Core contributions from Mekong River Commission projects have been supplemented by additional data and experiences from a large range of sources.

Matching data from different origins allowed for i) the development of hydrological and flooded vegetation models, and ii) the comparison of basinwide trends in fish migrations and catches.

The tools developed also include FishBase, a database on fish taxonomy and biology. The information available in FishBase can be used to determine functional guilds of fish based on their biological characteristics.

A variety of hydrological and environmental factors that influence fish production have been identified. This has led to the development of a qualitative Bayesian model of Mekong fish resources. The development of this model is proposed as a tool for promoting discussions and interactions between regional institutions, national and local government agencies responsible for fisheries and environmental management in the Mekong Basin.

Introduction

The Mekong River flows through China, Burma (Myanmar), the Lao PDR, Thailand, Cambodia and Vietnam. Since the mid-1990s, the Mekong River Basin has emerged from years of conflicts or national isolation and is now experiencing a rapid pace of political, social and economic changes, due among others to population growth (2.5% per year), an increase in the demand for resources and the opening up to regional and international markets.

The demand for water, that arises from irrigated agriculture, hydropower production, navigation and domestic and industrial water uses, is increasing dramatically. Water is still relatively abundant, but local people also depend heavily on aquatic resources for their nutrition (Ahmed et al. 1996; Baird et al. 1998, 2001; Shoemaker et al. 2001).

Rice and fish from capture fisheries are the two major staple food resources of the poor. Rice production in the Lower Mekong Basin amounts to about 30 million tonnes (riceweb.org). In addition to this dominant source of glucose, the harvest of aquatic animals as a source of protein is essential to the countries of the Mekong, amounting to one of the highest rates of fish consumption in the world (Figure 1).

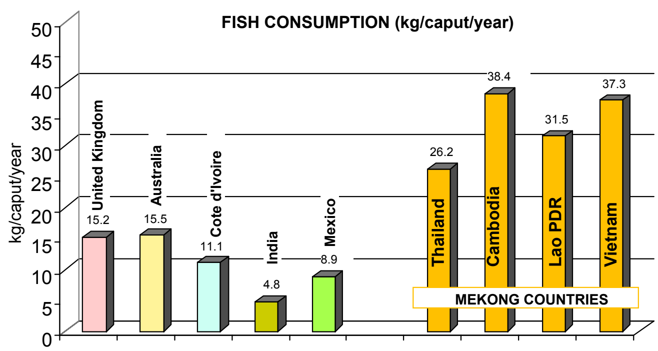


Figure 1: Fish consumption in a few countries worldwide

The estimated fish production of the Lower Mekong Basin countries, which has recently been re-evaluated by the Mekong River Commission, totals up to two million tons annually. The large majority of the supply is from capture fisheries, with aquaculture contributing only 17% of the total production in the Lower Mekong Basin (Jensen 2001). Aquatic resources not only consist of fish, but also of other types of aquatic wildlife (crabs, frogs, snails, etc), and aquatic plants (Shoemaker et al. 2001).

Access to common property resources such as fish and other aquatic animals is particularly crucial for landless people who cannot grow rice or livestock on their own. However at the national and regional levels the importance of water-dependant resources for livelihoods has been poorly recognised so far.

The sustainability of river-dependant food production is also linked to environmental issues. As a matter of fact, a large majority of the freshwater fish populations in the Lower Mekong basin migrate seasonally over long distances and between countries to spawn and feed in flooded areas such as the floodplain of the Tonle Sap Great Lake in Cambodia, the vast wetlands of Southern Laos (Siphandone), and the Vietnamese Delta (initial description of the system in Pantúlu 1986). The availability and quality of these inundated zones, in conjunction with hydrological factors, has a strong influence on total fish production (Baird and Phylavanh 1999; Baran et al. 2001a).

Therefore an integrated approach of water, water-dependant resources, and the natural environment is necessary to avoid unsound development options that would threaten food security basinwide. The Mekong River Basin provides a critical example of the interactions and possible conflicts over water in a context of rapid development, and there is an urgent need for management tools in the region. Below, we detail a few activities that have recently been developed by ICLARM and partners to provide a set of operational tools for integrated management of the Mekong River Basin water and water dependent resources. The overall strategy is based on the principles of partnerships for synergy, optimal use of existing information, and basinwide approaches.

Among the partners who participated in this work, the following are worthy of particular mention:

1) the Mekong River Commission
    - Hydrology Programme (provision of hydrological data)
    - Fisheries Programme (provision of fisheries statistics and data)
    - Environment Programme (provision of water quality data),

2) the International Water Management Institute (hydrological data and modelling)

3) the Global Association for People and the Environment (fisheries data).

These interactions have resulted in the first comprehensive hydrological model of the Mekong River including the Tonle Sap reversing flows system; a model of the surface of flooded vegetation in the Tonle Sap area; the first scientifically underpinned review of parameters driving the fish production basinwide, and a model of the Mekong fish production in relation to its environment and river hydrology.

A hydrological model of the Mekong River

The International Water Management Institute based in Sri Lanka developed a hydrological model of the Mekong River, the only one including the Tonle Sap system so far (Al Soufi 2000).

This model is freely available on CD-ROM at IWMI (Kite 2000c). It is based on SLURP, a former IWMI basin model that simulates the hydrological cycle from precipitation to runoff. It divides the basin into sub-basins using topography from a digital elevation map. The sub-basins are further divided into classes of different land covers using a digital land cover classification. The nature of the ground is taken into account through soil maps. The hydrological model simulates the vertical water balance, transforming daily precipitation into evaporation (depending on temperature, wind, cloud cover, etc), vegetal evapotranspiration (radiation measures), water retention (canopy storage, snowpack, soil moisture and ground water), and runoff. This is done separately for each land cover within each sub-basin (Figure 2).

The hydrological model encompassing the Tonle Sap River reversing flow has resulted in a daily estimate of the Mekong discharge (from China to the upper non-tidal delta) and of the Tonle Sap River discharge, from 1994 to 1999. This modelling started with the year 1994 in order to link the model with fisheries statistics, and stopped in December 1998 due to the absence of rainfall data in 1999.

The IWMI Mekong hydrological model potentially includes the effects of reservoirs, regulators and water extractions (Kite 2000a, 2000b). However the operating rules for dams on the Mekong and its tributaries are not available from the Mekong River Commission or from the Internet. There are nine large dams in the Lower Mekong Basin, mostly in Thailand (Piper et al. 1991). If the operating rules for these dams were available, they could be incorporated into the model. However, this lack of data may not be too critical since, in 1991, the total area of the tributary basins that fed existing reservoirs was less than five percent of the total Mekong Basin area, and accounted for less than seven percent of the total annual flow (Piper et al. 1991).

Another limitation of this model is that the available data are not always accurate or sufficient. For example, the 30 arc-second (approximately 1km) resolution USGS Digital Elevation Model had to be modified before the topographic analysis software could correctly define the river channels in the delta area and the mountain gorge area of Yunnan Province in China. Secondly, it was found that the climate stations available were not well distributed across the basin. This may have resulted in less than ideal simulation of runoff from those areas that lack data.

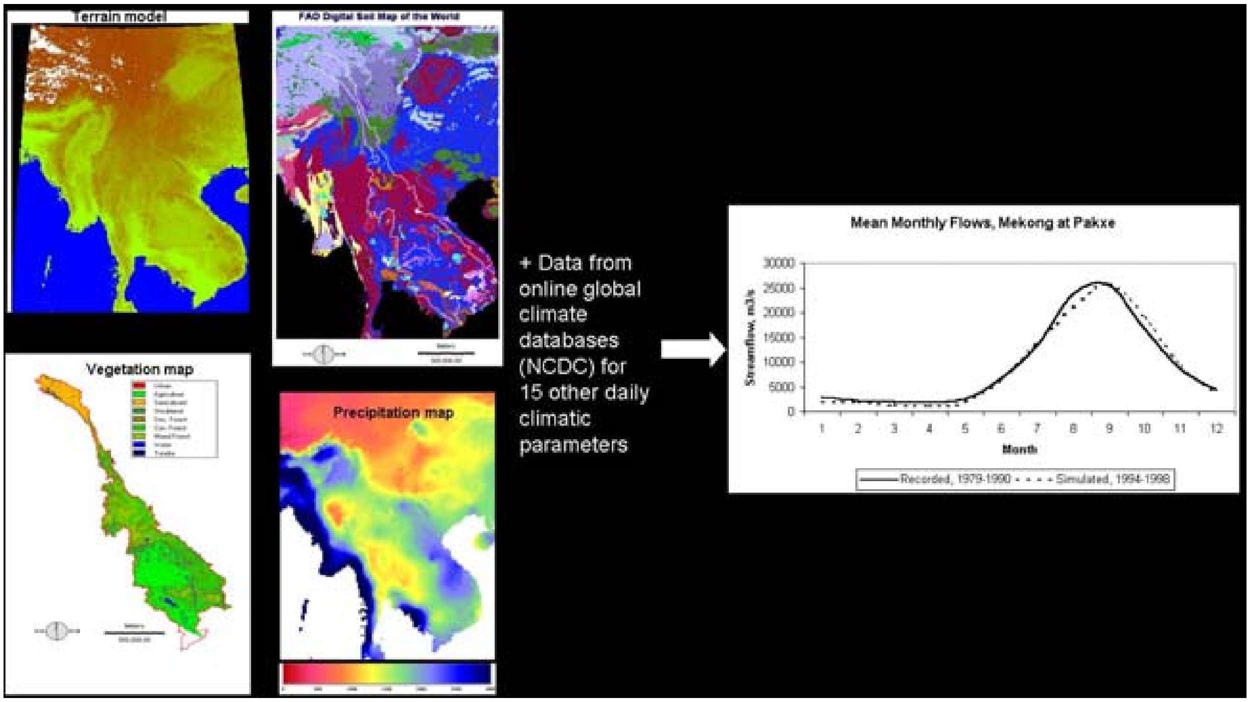


Figure 2: Inputs and output of the IWMI hydrological model of the Mekong River

A model of the flooded vegetation in the Tonle Sap Great Lake

For the purpose of fishery-environment relationship modelling, the hydrological model has been supplemented by the integration of a detailed Digital Elevation Model available for the Tonle Sap zone (SOGREAH/UNESCO 1966, Sopharith 1997) and a GIS-referenced map of land cover in the Tonle Sap floodplain (UNDP/FAO 1994). This resulted in an assessment of the surface of each land cover flooded each year in this zone (Figure 3; Kite 2000b).

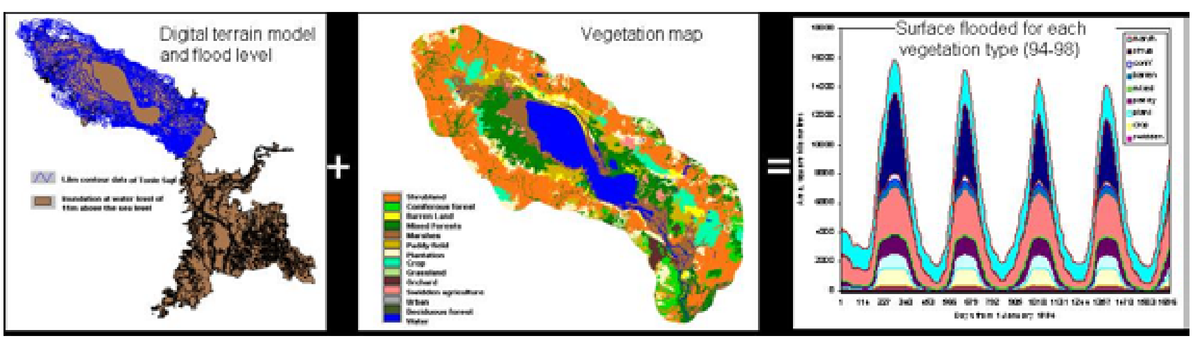


Figure 3: Quantification of the surface flooded daily for each land cover around the Tonle Sap Great Lake

One must note that these estimates of flooded vegetation are based on the 1993-1994 mapping, and have probably changed since.

Identification of parameters driving the fish production basinwide

On the ecological side, the various parameters possibly driving the fish production in tropical rivers in general have been identified based on an extensive review (Baran and Coates 2000, Baran et al. 2001a). Given the absence of long-term monitoring basinwide, it was impossible to relate global fish catches to hydrological or environmental variables on a large scale. However the influence of several hydrological or environmental variables on fish production has been demonstrated case by case in multiple instances. A few examples are given below.

Example: importance of flood timing to fish

The seven-year monitoring of small-scale fisheries in Southern Laos (Baird 1998; Baird et al. 2000; Baird and Flaherty 2000) has provided extremely useful information about the ecology of fishes in the region (Baran and Baird in prep.). Figure 4 demonstrate that the migration of the catfish *Pangasius krempfi* is triggered by a rise in water levels (as mentioned in Roberts and Baird 1995; Baird et al. 2000). Should this rise be delayed or minored by dams, the migration would be similarly affected.

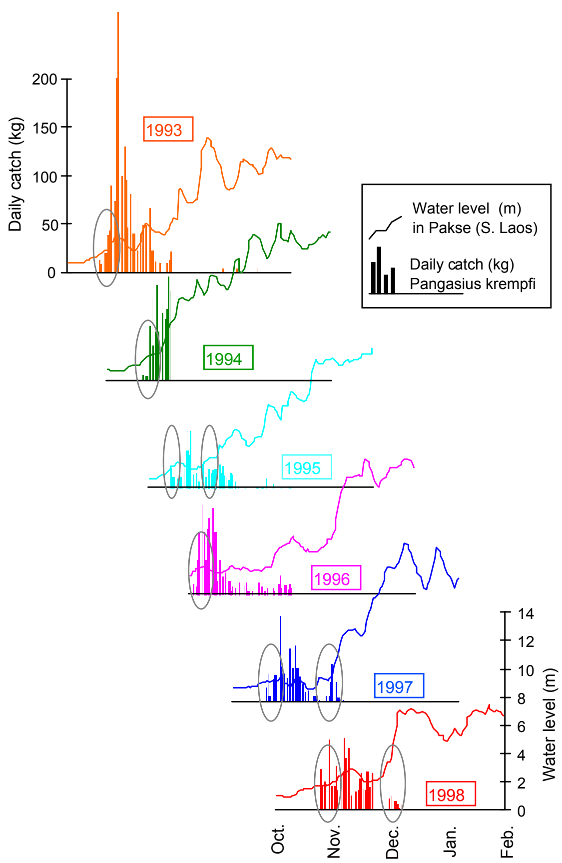
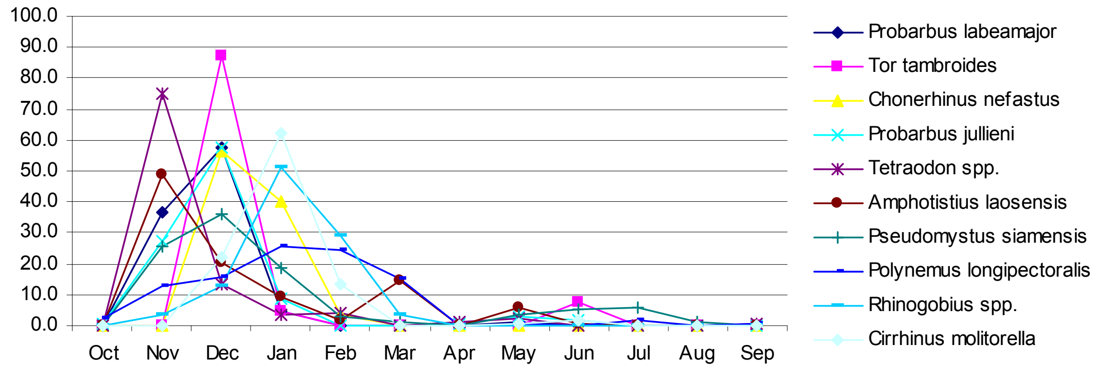


Figure 4: Migration peak of Pangasius krempfi *(catfish) in relation to water level rise*

Example: migration patterns

The same database provided quantified information about the timing of the migrations of 110 fish species, many of which exhibiting strong migration behaviour (over long or short distances, for trophic or reproduction reasons). Figure 5 shows examples for 20 species. These results are coherent with those of the MRC project on migrations basinwide (Poulsen and Valbo 2001) that used local fisher knowledge to study the migration patterns of 50 species.



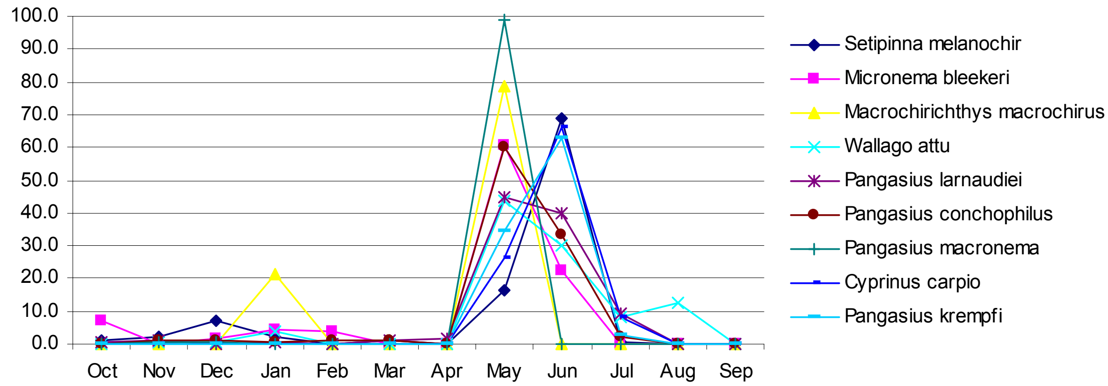


Figure 5: Migration patterns of 20 species in Southern Laos

A summary of the parameters driving fish production basinwide is given in Figure 6; three basic groups of parameters can be listed:
i) hydrological factors, that comprise flooded area (area of floodplain available to fish), but also the flood duration, the regularity of flooding, and timing of floods (see example Figure 4);
ii) environmental factors, particularly the type of vegetation flooded and the presence of refuges for fish during the dry season (ponds in floodplains or pools in the mainstream).
iii) ecological factors, in particular migrations whose importance in the Mekong river system has been demonstrated in various publications.

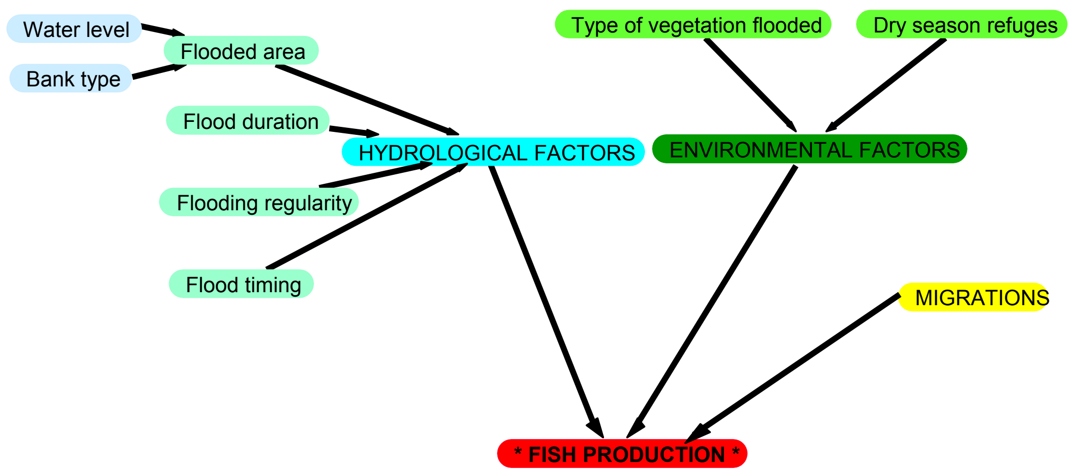


Figure 6: schema of variables influencing the fish production basinwide

These are the basic factors of the natural Mekong system influencing fish production. The work detailed below has also pointed out the importance of additional factors such as fishing pressure over decades and the strong influence of a few dominant fish species in overall production statistics (Baran et al. 2001b)

FishBase as a knowledge base for Mekong fishes

FishBase, developed by ICLARM since 1994 (Froese and Pauly 2000, 2001), is a repository of all the scientific information of a taxonomic and biological nature on the fishes of the world. More than 25,000 species have been listed in FishBase 2000, and this information is available online (www.fishbase.org).

Recent efforts to upgrade and update the information on the fishes in Indochina have resulted in a total of 744 fish species being referenced for the Mekong River Basin. FishBase lists the available biological information about these species, namely the maximum length, length at maturity, length for maximum yield, life span, generation time, age at first maturity, trophic level, growth, diet, endemism, migration behaviour, etc.

In the case of Mekong fishes, this information was applied to the bagnet fishery of Cambodia (Lieng et al. 1995, Baran et al. 2001c); it was analysed using multivariate statistical methods and resulted in a typology of species having similar biological or commercial characteristics (Figure 7).

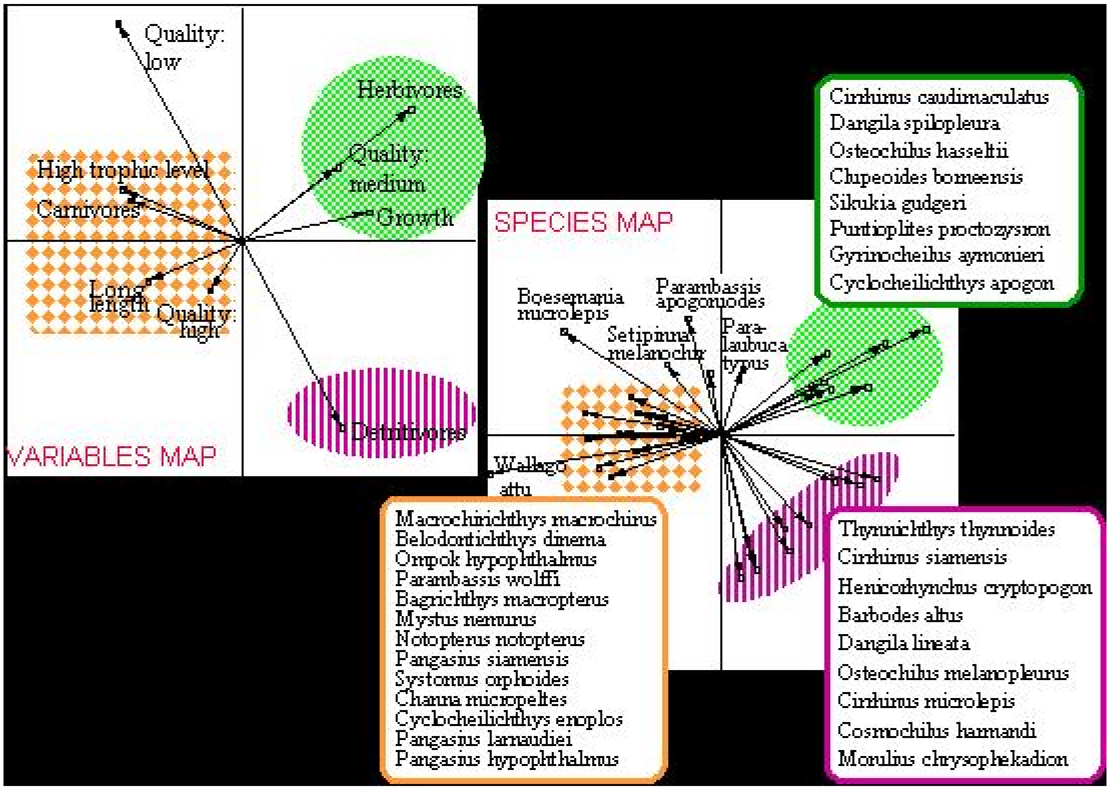


Figure 7 : Factorial map of the dominant species of the dai fishery, and their characteristics

This approach also allowed the identification of knowledge gaps, either about certain species or about certain variables such as life span, generation time or age at first maturity (which are critical parameters for the management of a fishery).

A model of the Mekong fish resource

The various parameters listed in Figure 6 interact together in a complex way, resulting in high or low fish catches in given years. How can these interactions be quantified, and can fish production be predicted? Recent works (Baran in press) have shown that the current paucity of published information on fish and fisheries in the Mekong Basin does not permit a classical fishery science approach or an ecological modelling approach, at least not for the next several years (at best, if monitoring programmes are implemented now).

We therefore applied a Bayesian approach (Baran and Cain 2001), in which the variables are those identified in Figure 6, and are defined as nodes that are given status (e.g.: “Water level” can be “High” or “Low”). The nodes are then interconnected by arrows representing relationships; these relationships are expressed in terms of probabilities based on the best available knowledge (e.g. there is a 100% chance of having a large flooded area when the water levels are high and the floodplain is natural, but there is only a 20% chance of having a large flooded area when the water levels are high but the river is dominantly embanked). The input can be either quantitative (data, equations) whenever data are available, or based on expert opinion in the case of lack of quantitative data. Probabilities are entered in mother nodes (e.g. water level, flooded area), and in daughter nodes the probability resulting from previous interactions is computed according to Bayes formula (Figure 8).

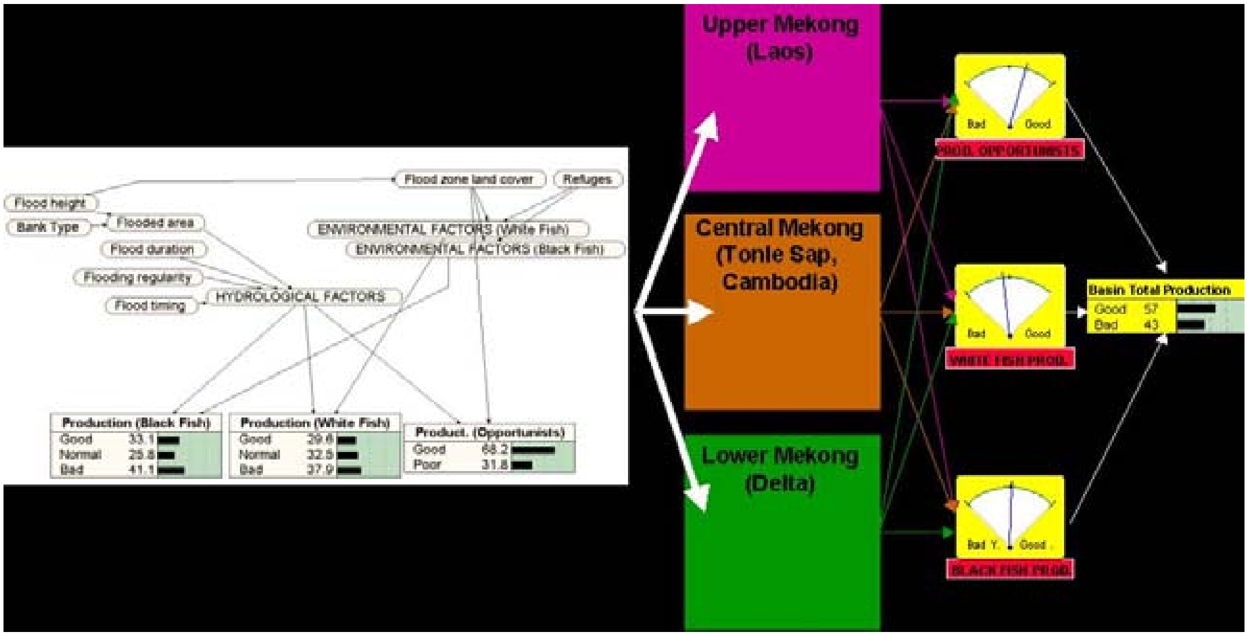


Figure 8: Schematic representation of a Bayesian model of the Mekong fish resource

Conclusions

By optimising the use of available information, the different approaches presented above have contributed to a better understanding of the fish resources of the Mekong region and their dependency upon hydro-environmental factors. These factors need to be taken into consideration for the sustainable management of resources in the context of agricultural and industrial development. The provision of tools for managers is of critical importance in such a context, and the fast pace of development, as opposed to the slow pace of traditional science, requires new approaches and tools. Decision support systems such as Bayesian networks, being based on available knowledge, even if it is of a qualitative nature, are promising and should be further developed.

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